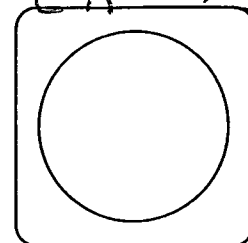


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TELEPHONE: (202) 223-8100 TELEX: EARTHSAT64449

March 1, 1973

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

ATTENTION: Distribution

RE: Bi-Monthly Progress Report-SR #141
ERTS-1, Snow Enhancement: NAS5-21744

Gentlemen:

Earth Satellite Corporation (EarthSat) is pleased to submit a progress report for the period of January 1, 1973 to February 28, 1973. To facilitate NASA's review, a consistent format has been adopted for all progress reports prepared by Geosciences and Environmental Applications Division. A Task Status Report can be referenced in Appendix A.

- A. TITLE: Facilitating the Exploitation of ERTS-Imagery Using Snow Enhancement Techniques (SR #141) - NAS5-21744
- B. PRINCIPAL INVESTIGATOR: Dr. Frank J. Wobber (P-511)
- C. CONTRIBUTORS: Dr. Frank J. Wobber
Mr. Kenneth Martin
Mr. Roger Amato
- D. SUMMARY OF ACCOMPLISHMENTS: Field investigations within the New England test area (Massachusetts and Connecticut) have been coordinated with an ERTS-1 overflight to facilitate the acquisition of timely and reliable data on snow conditions. Analytical studies have been conducted to compare fracture data yield from each of the four MSS bands. A paper detailing the results, findings and benefits of the experiment has been prepared and will be presented at the March ERTS-1 symposium.

Original photography may be purchased from
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

351

(E73-10345) FACILITATING THE EXPLOITATION
OF ERTS IMAGERY USING SNOW ENHANCEMENT
TECHNIQUES Bimonthly Progress Report, 1
Jan. - 28 Feb. 1973 (Earth Satellite
Corp.) 35 p HC \$3.75
N73-19344
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G3/13 00345
CSC 08L

The first images of snow-covered terrain within the New England have been received. Fracture analysis is being conducted (Figure 1). A summary of the major accomplishments follows:

- Field investigations were conducted within the New England test area coincident with the February 12 overpass of the ERTS-1 satellite. General observations are referenced in the Snow Cover Observation report (Appendix B).
- A snow depth map has been compiled for the New England test area based on data supplied through EarthSat's snow depth reporting network (supplemented by snow depth readings taken by the investigators). The map will be used to compare snow depth with fracture data yield and thus establish the working limitations of snow enhancement technique.
- Approximately 50 bedrock joint readings were taken from outcrops during field investigations and will be utilized to confirm the validity of lineaments interpreted from ERTS-1 imagery.
- Low altitude, light aircraft vertical and oblique photography was collected by the investigators during the February 12th ERTS-1 overflight. A time coincident with the overpass was chosen to minimize climatic and solar illumination variables. The geological value of oblique imaging is being tested. Results already obtained from analysis of these data are referenced in the Significant Results section.
- ERTS-1 image analysis (1096-15072 and 1096-15065) has confirmed that MSS bands 5 and 7 provide the greatest fracture detail for snow-free areas. MSS Band 5 appears to supply the greatest amount of fracture detail in snow-covered terrain but further studies are needed to confirm this.
- The first ERTS-1 images (1132-15074 and 1168-15065) of snow-covered terrain within the New England test area have been received and are being analyzed (Figure 1).
- The Final Report Outline has been revised and updated. A new section dealing with Cost Benefit Analysis has been included as an anticipated add-on.
- Draft versions of sections of the Final Report have been prepared.

- A paper detailing the results, findings and projected benefits of the experiment will be presented by the principal investigator at the March ERTS-1 symposium. The abstract is included in Appendix C.
- Snow enhancement techniques have been made available to the mineral industry as a step leading to cost-benefit analysis of ERTS-1 technology (Appendix D).

E. SIGNIFICANT RESULTSS

Results/Findings

- New fracture detail within the New England test area has been acquired using ERTS-1 imagery.
- MSS/Bands 5 and 7 supplied the greatest amount of fracture detail in snow-free terrain.
- Snow-cover provided added enhancement for viewing and detecting topographically expressed fractures and faults.
- Heavy snow-cover (e.g. >9 inches) accentuates major topographically expressed geological features (e.g. thrust faults)
- Light snow dusting (e.g. <1 inch) accentuates subtle fracture detail.
- Snow-cover accentuates drainage patterns which are indicative of lithological and/or structural variations.
- Vegetative alignments indicative of fracture control were enhanced by snow cover.^{1/}

Projected Benefits

- Development of snow enhancement techniques promotes more full utilization of wintertime ERTS imagery.
- Photogeological fracture mapping will be accelerated by proper utilization of snow cover as an enhancement tool.
- Evolution and development of the experiment within a short period of time from a research oriented project toward a practical, cost effective method of obtaining geological data.
- Technique has been made available to mining industry.

^{1/}

Established from light altitude aircraft coverage.

F. PROBLEMS

- A lack of measurable snowfall within the Maryland-Virginia test area has prevented the investigators from making observations which are critical in the definition of the mechanism of snow enhancement and in the isolation of the primary factors (e.g. soil differences, thermal/moisture properties of fracture zone materials, etc.) responsible for snow-covered feature enhancement. Additional funding is justified for continuance of the experiment through an additional snow-covered period.
- The inferior quality of many paper prints does not allow direct mapping of fracture data. Unanticipated costs are accruing from increased time required for analysis of sub-standard images and need for commercial enlargements to replace low quality paper prints. The Technical Monitor has been notified of the processing problems.

G. RECOMMENDATIONS FOR TECHNICAL CHANGES: NoneH. CHANGES TO STANDING ORDER FORMS: NoneI. OVERVIEW OF INVESTIGATION:

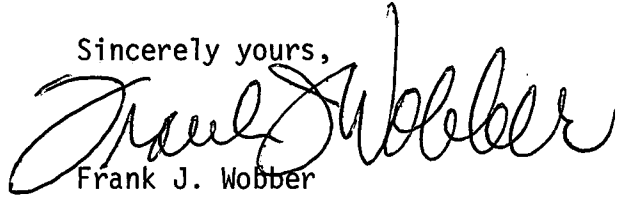
New fracture detail within the New England test area has been interpreted from ERTS-1 imagery. Comparative analysis of snow-free ERTS-1 images (1096-15065 and 1096-15072) has demonstrated that MSS Bands 5 and 7 supply the greatest amount of fracture detail. Interpretation of the first snow-covered ERTS-1 images (1132-15074 and 1168-15065) in correlation with ground snow depth data indicates that a heavy "blanket" of snow (e.g. > 9 inches) accentuates major structural features while a light "dusting" (e.g., < 1 inch) accentuates more subtle topographic expressions. Snow cover was found to accentuate drainage patterns which are indicative of lithological and/or structural variations. Snow cover provided added enhancement for viewing and detecting topographically expressed fractures and faults. A recent field investigation was conducted within the New England test area to field check lineaments observed from analysis of ERTS-1 imagery, collect snow depth readings and obtain structural joint readings at key locations in the test area. Low altitude, light aircraft vertical and oblique photographs were collected by the investigators over the New England test area coincident with the February 12 ERTS-1 overpass. The photography will be coordinated with field fracture measurements to verify lineaments mapped from ERTS-1 imagery.

Dr. Frank J. Wobber

-5-

SR #141 NAS5-21744

Sincerely yours,

A handwritten signature in black ink, appearing to read "Frank J. Wobber". The signature is fluid and cursive, with the first name "Frank" and last name "Wobber" clearly distinguishable.

Frank J. Wobber

Director

Geosciences and Environmental
Applications Division

FJW/1a1

SIGNIFICANT RESULTS

January 1, 1973 - February 28, 1973

Results/Findings

- New fracture detail within the New England test area has been acquired using ERTS-1 imagery.
- MSS/Bands 5 and 7 supplied the greatest amount of fracture detail in snow-free terrain.
- Snow-cover provided added enhancement for viewing and detecting topographically expressed fractures and faults.
- Heavy snow-cover (e.g. > 9 inches) accentuates major topographically expressed geological features (e.g. thrust faults)
- Light snow dusting (e.g. < 1 inch) accentuates subtle fracture detail.
- Snow-cover accentuates drainage patterns which are indicative of lithological and/or structural variations.
- Vegetative alignments indicative of fracture control were enhanced by snowcover.^{1/}

Projected Benefits

- Development of snow enhancement techniques promotes more full utilization of wintertime ERTS imagery.
- Photogeological fracture mapping will be accelerated by proper utilization of snow cover as an enhancement tool.
- Evolution and development of the experiment within a short period of time from a research oriented project toward a practical, cost effective method of obtaining geological data.
- Technique has been made available to mining industry.

^{1/}

Established from light altitude aircraft coverage.

March 1, 1973

PROGRESS REPORT SUMMARY

Reporting Period: January 1, 1973 - February 28, 1973

CATEGORY: 8-Interpretation Techniques Development

SUB-CATEGORY: C-General

TITLE: Facilitating the Exploitation of ERTS-Imagery Using Snow Enhancement Techniques - SR #141: NAS5-21744

PRINCIPAL INVESTIGATOR: Dr. Frank J. Wobber (P-511)

CO-INVESTIGATOR: Mr. Kenneth R. Martin

SUMMARY:

New fracture detail within the New England test area has been interpreted from ERTS-1 images. Comparative analysis of snow-free ERTS-1 images (1096-15065 and 1096-15072) has demonstrated that MSS Bands 5 and 7 supply the greatest amount of geological fracture detail. Interpretation of the first snow-covered ERTS-1 images (1132-15074 and 1168-15065) in correlation with ground snow depth data indicates that a heavy "blanket" of snow (e.g., > 9 inches) accentuates major structural features while a light "dusting" (e.g., < 1 inch) accentuates more subtle topographic expressions. Snow cover was found to accentuate drainage patterns which are indicative of lithological and/or structural variations. Snow cover provided added enhancement for viewing and detecting topographically expressed fractures and faults. A recent field investigation was conducted within the New England test area to field check lineaments observed from analysis of ERTS-1 imagery, collect snow depth readings and obtain structural joint readings at key locations in the test area. Low altitude, light aircraft vertical and oblique photographs were collected by the investigators over the New England test area coincident with the February 12 ERTS-1 overpass. The photography will be coordinated with field fracture measurements to verify lineaments mapped from ERTS-1 imagery.

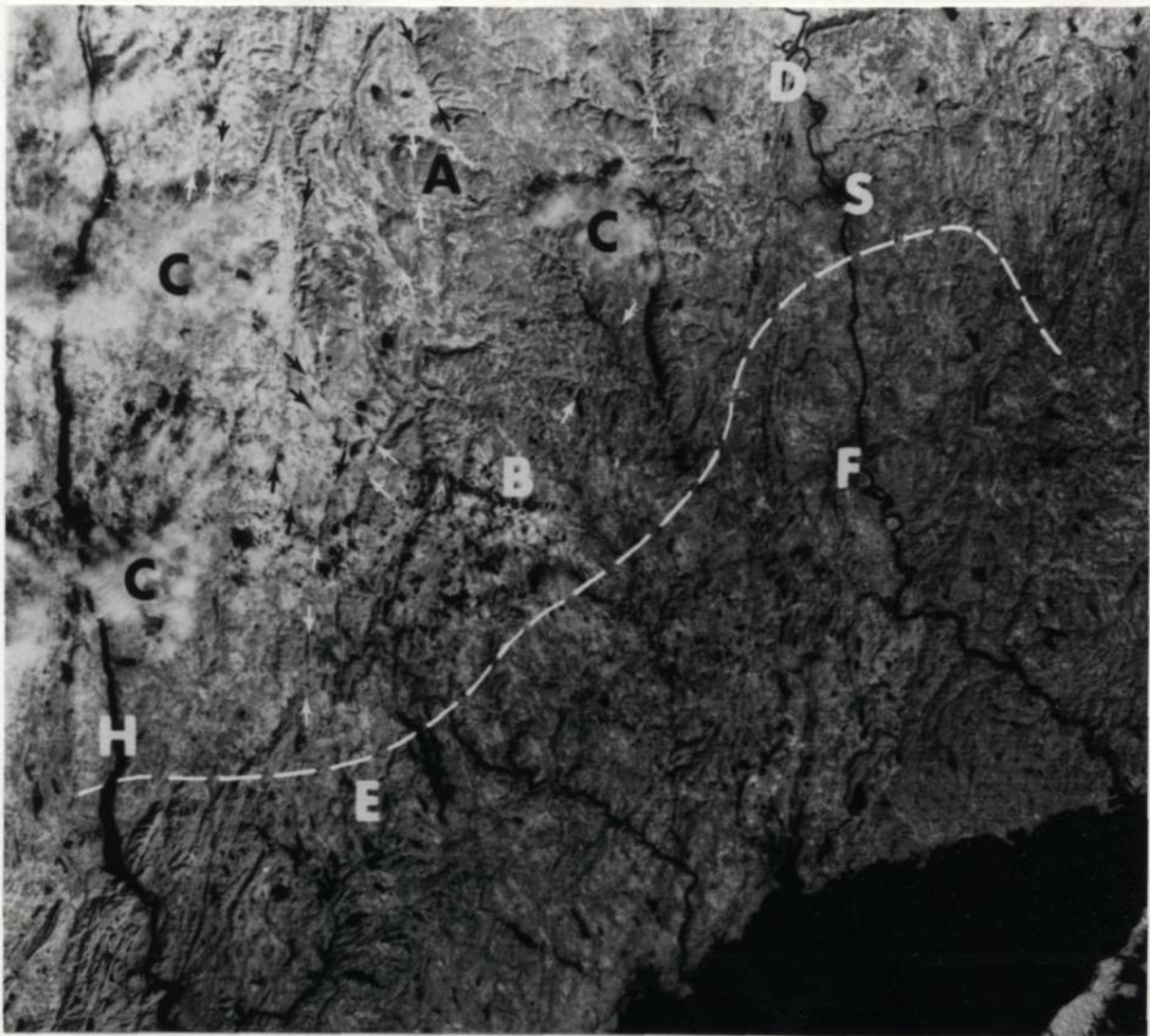


FIGURE 1: ERTS-1 image (1132-15074-7) at 1:1,000,000 scale acquired on December 2, 1972. The imaged area is partially snow-covered and includes Connecticut, southwestern Massachusetts and the eastern edge of New York. The southern limitation of snow cover is indicated by a dashed line. Geographic reference points include Hartford, Connecticut (F), Springfield, Massachusetts (S), the Hudson River (H) and Mount Tom (D). Partial cloud cover (C) obscures ground detail, but can be distinguished from snow cover following careful image analysis. Based on field observations, snow depths vary from <1 inch just north of the line to 9 inches in the northwestern corner of the photo. Low angle solar illumination (22 degrees) accentuates subtle topographically expressed features (E) not as easily detected with a higher sun angle. Northwesternly trending thrust fault blocks (A) are accentuated by a thick (approximately 9 inches) snow cover. Light-toned (snow-enhanced) lineaments (B) approximate the direction of recorded glacial striations and are probably of glacial origin. Dark-toned (snow-free) lineaments (arrows) represent a small sampling of mappable lineaments within the snow-covered areas. A complete analysis is now in progress. Lineaments will be confirmed through subsequent geological validation procedures. Analysis was confined to the area of greatest snow visibility within the western portions of Connecticut and Massachusetts.

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ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

DATE March 1, 1973

PRINCIPAL INVESTIGATOR Frank J. Wobber

GSFC _____

ORGANIZATION EarthSat

NDPF USE ONLY

D _____

N _____

ID _____

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Lake	River	Clouds	
1023-15005-4 01	X	X		Basin
1023-15005-5 01	X	X		Coast Line
1023-15005-6 01	X	X		Lineament
1023-15005-7 01	X	X		Piedmont
				River
1077-15011-4 01				
1077-15011-5 01				
1077-15011-6 01				
1077-15011-7 01				
1167-1				
1167-15011-4 01	X	X		Snow
1167-15011-5 01	/X	X		
1167-15011-6 01	X	X		
1167-15011-7 01	X	X		
1024-15064-4 01	X	X		Coast Line
1024-15064-5 01	X	X		Coastal Plain
1024-15064-6 01	X	X		Flood Plain
1024-15064-7 01	X	X		Dendritic Drainage
				Lineament
1132-15074-4 01				
1132-15074-5 01				
1132-15074-6 01				
1132-15074-7 01				
1096-15065-4 01	X	X		Basin
1096-15065-5 01	X	X		Piedmont
1096-15065-6 01	X	X		Meander

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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 BLDG 23 ROOM E413
 NASA GSFC
 GREENBELT, MD. 20771
 301-982-5406

ERTS IMAGE DESCRIPTOR FORM

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DATE March 1, 1973

PRINCIPAL INVESTIGATOR Frank J. Wobber

GSFC _____

ORGANIZATION EarthSat

NDPF USE ONLY

D _____

N _____

ID _____

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Lake	River	Ridges	
1096-15065-7 01	X	X		Bedding
1168-15065-4 01	X	X		Snow
1168-15065-5 01	X	X		
1168-15065-6 01	X	X		
1168-15065-7 01	X	X		
1079-15122-6001	X	X	X	Anticline
1079-15122-7001	X	X	X	Bedrock
				Dendritic Drainage
1061-15120-4001	Cloud-covered- 70%			Fault
1061-15120-5001				Geofracture
1061-15120-6001				Lineament
1061-15120-7001				Monoclinial Valley
				Mountain
				Massif
				Rectangular Drainage
				Thrust Fault
				Valley
1169-15123-4001	X	X	X	Snow
1169-15123-5001	X	X	X	
1169-15123-6001	X	X	X	
1169-15123-7001	X	X	X	
1167-15013-4 01	X	X		
1167-15013-5 01	X	X		
1167-15013-6 01	X	X		
1167-15013-7 01	X	X		

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).



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APPENDICES

APPENDIX A

APPENDIX A
TASK STATUS REPORT

TASK	STATUS	COMMENTS
PHASE I		
1.0	Establish Technical Interface with NDPF	Completed 6/30/72 Meetings held with the scientific monitor: ERTS-simulation U-2 aircraft imagery analyzed.
2.0	Assemble Geological Maps and Snow Cover Data	Completed 10/31/72 Subscription to New England Climatological Data: State geological maps of Massachusetts, Connecticut, Vermont, New Hampshire, and geological quadrangle maps for western Massachusetts purchased and analyzed.
3.0	Select and Establish Snow Points	Completed 2/28/73 A comprehensive net of weather stations has been organized. Physical ground points for light aircraft survey have been minimized.
4.0	Base Map & Under-flight Preparation	Completed 10/31/72 Base map scale determined: Other New England investigators contacted.
5.0	Lineament Map Preparation	Completed 8/30/72 Radar imagery of Massachusetts, Connecticut, and Rhode Island was intensively analyzed to prepare geological lineament maps of the test area.
6.0	Snow Cover and Snow Melt Survey	Completed 12/31/72 Survey package designed and sent to newspapers in low density snow depth reporting areas. Readers indicating interest have been supplied with snow-depth reporting materials.
PHASE II		
7.0	Select & Analyze Snow Free ERTS Imagery	Completed 2/28/73 All ERTS-1 imagery of the test area analyzed upon receipt. Images 1096-15072-5 & 7 and 1096-15065-5 & 7 of the New England Test area and 1062-15190-5 & 7 of the Maryland Test area are being enlarged to a 1:250,000 scale to serve as a photo base map.

TASK	HEADING	STATUS	COMMENTS
2.0	Analyze Snow-Covered Imagery	Underway	All ERTS-1 imagery of the test area analyzed upon receipt. Intensive analysis of frames 1132-15074 & 1168-15065 is being conducted for comparison with snow-free data.
 3.0	Prepare & Submit A Preliminary Data Analysis Plan	Completed 12/31/72	A Data Analysis Plan has been submitted and approved by the ERTS Contracting Officer.
PHASE III			
 1.0	Modify Manual Optical & ADP Enhancement Techniques.	Completed 2/28/73	A re-evaluation of techniques and approach has been conducted. No major changes were necessary - minor modifications have been integrated.
2.0	Process ERTS Imagery Though Last Snow-Covered Period.	Underway	
3.0	Prepare Final Report	Underway	Sections of Final Report are being written as the experiment progresses. Sections I, II and III (Introduction, Background and Design) complete in draft form.
4.0	Prepare NDPF User Manual	Pending Completion of Snow-Cover Analysis	



- Completed Tasks

APPENDIX B

February 14, 1973

SNOW COVER OBSERVATIONS

WITHIN THE NEW ENGLAND

TEST SITE

(February 10 - February 13, 1973)

(February 10 - February 13, 1973)

Prepared By

Kenneth R. Martin

and

Roger V. Amato

Prepared By

EARTH SATELLITE CORPORATION
Geosciences and Environmental
Applications Division
1747 Pennsylvania Avenue, N. W.
Washington, D.C. 20006

Earth Satellite Corporation

FOR INTERNAL USE

CONTENTS

GENERAL COMMENTS AND OBSERVATIONS

SNOW COVER PATTERNS

LINEAMENT TONE

FRACTURE ENHANCEMENT

LAND USE DISCRIMINATION

OBSERVATION SUMMARY

GENERAL COMMENTS AND OBSERVATIONS

Weather - - - - - all days were generally clear and sunny affording maximum snow cover/snow-free tonal contrasts and topographic shadowing; at ERTS overflight time (approximately 10:07 AM February 12) clear skies were observed over northwestern Massachusetts and were believed to extend at least as far south as New Haven, Connecticut; general ERTS conditions were thought to be excellent to good - excellent.

Snow Cover - - - - - southern Connecticut was effectively snowfree with a light discontinuous cover (approx. 2 inches) occurring north of Hartford, Connecticut; in southern Massachusetts snow cover varied from sporadic - discontinuous; north of Great Barrington snow cover became even and continuous; maximum observed cover was 12 inches in the Hoosac Mountains and in the bottoms of deep, narrow valleys; cover was lightest on windswept open areas and in urban areas.

Snow Depth Readings - - approximately 75 snow depth readings were taken throughout central and western Massachusetts and northern Connecticut; these readings will be combined with postcard readings to compile detailed snow depth point and isopach maps which will be utilized to determine the influence of snow depth on data yield.

Joint Measurements - - - approximately 50 strike and dip measurements of joints were made on bedrock outcrops throughout western Massachusetts and Connecticut; these measurements will be used to substantiate fractures mapped from orbital and aircraft imagery. Preliminary analyses indicate that measurements correlate well with most of the fracture trace directions mapped to date.

Fractures
Fractures - - - - - several high density fracture areas were identified within the test area from a light aircraft, low altitude observations; numerous photographs were taken; actual enhancement of fractures by snow cover was observed.

Snow Enhancement - - - fracture enhancement was noted from aircraft observations; land use discriminations were enhanced by snow cover; joint systems were enhanced in ground observations; outfalls were conspicuously enhanced; bedding planes of dark rock outcrops on steep slopes which are normally not evident were greatly enhanced by snow cover. (Figure 3).

Low Altitude Aircraft - - flight was made between 8:30 am - 10:45 am on February 12 to coincide with the OERTS overflight; cruising altitude was between 4,000-5,000 ft. alt. (Figure 2).

Vegetation - - - - - a highly mixed composition of deciduous and coniferous vegetation occurred on mountain slopes with deciduous predominating; floodplains and terraces were intensively farmed with agricultural intensity decreasing in the foothills area; fracture detail from aerial observation was greatest in areas of deciduous vegetative cover.

SNOW COVER PATTERNS

- Light Snow Cover Was Observed To Be Wind Blown Into Slight Depressions Forming Miniature Snow Catchment Basins; Snow Cover <1" Accentuates Micro Relief Differences; These Depressions Apparently Did Not Have Significantly Different Permeability/Moisture Properties Than Rises and Micro-Ridges.
- In Cultivated Fields, Drainageways That Were Left Vegetated (grass) Retain A Light Snow Cover While Barren (cultivated or harvested) Fields Remain Almost Snow-Free.
- Snow Remains In Concrete Drainageways Along Highways - This Was Believed To Be Due To Lower Permeability Than Surrounding Vegetated Areas Which Had Much Less Snow On Pools Conductance Loss Ground Heat.
- Drainageways In Grassy Fields Are Snow-Free Due To Actual Water Run-Off and/or Higher Moisture Content Of Surficial Materials (Confirmed).
- Snow Cover Is Regionally Thickest In Deep Narrow Valleys and On High Mountain Slopes.
- Snow Melts and Is Cleared From Urban Areas Much Quicker Than Surrounding Country; Streets, Buildings and Lawns Are All Primarily Free From Snow In Urban Areas (Or Cover Is Very Sporadic) While Surrounding Countryside May Have More Than Two Or Three Inches Of Even Snow Cover.

- Slope Aspect Appears To Have The Greatest Effect Of Any Factor On Snow Melting Patterns After A Relatively Even Cover Has Been Deposited (e.g. > 3 inches).

South Facing Slopes Are Generally Snow Free (As Expected)
Even In Areas Of Snow Cover Overall: COVWE

- Melting Around Concrete Road Posts and Trees Which Act As Conductors Of Solar Heat; A Higher Permeability May Exist Around Base Where Soil Is Disturbed.
- Meander Scrolls Generally Retain Snow Longer Than Adjacent Alluvial Sediments; Some Have Ice Cover.
- Outfalls Are Conspicuous As Unfrozen (Very Dark-Toned) Areas Which Are Readily Contrasted With Surrounding Ice Or Snow Cover; Their Areal Extents Appear To Vary In Size As A Function Of Turbidity Or Heat Of Current.
- Low Grassy Vegetation Tends To Melt and/or Obscure Light (1-3 in.) Snow Cover.
- Some Forest Floor Snow Is Obscured By Fallen Pine Needles And Leaves.

LINEAMENT TONE

- Snow-Covered Light-Toned Lineaments

Ski Slopes - contrast sharply with coniferous vegetation,
less sharply with deciduous.

Transmissions Lines - are snow-covered and are contrasted
sharply with adjacent forest cover
which has snow-obscuring vegetation. (Fig. 4)

Timber Roads or Fire Lanes - same as above

- Snow-Free And/Or Dark-Toned Lineaments

Roads - salt or residual snow on roads may reduce tonal contrast; cleared blacktop roads have sharp contrast with snow piled along edges.

Fractures - dark-toned, believed to be caused by shadowing and differential melting

Railroads - tracks and sloped gravel abutting tracks are bare; snow-covered in-between track sets and on outside edges-should be very sharp visual contrast and increase resolution

Runways - asphalt runways contrast sharply with snow piled along edges

Stone Fences - easily identified at 5,000 ft.; should not be a factor with ERTS

Field Lineaments - manure spreading in unvegetated agricultural fields creates a sharp contrast between dark-toned, affected area and light-toned, unaffected, snow-covered area

SNOW ENHANCEMENT OF GEOLOGICAL FEATURES

Fractures - were readily observed (5,000 ft. alt.) particularly in areas of deciduous vegetation where ground detail was highly visible; definite fractures were generally difficult to discern in snow-covered open areas - this was thought to be due to excessive snow depth (reference detailed snow depth map to be developed).

- were slightly darker-toned than surrounding snow-covered areas; it was undetermined if differential melting or topographic shadowing was the principal cause of the darker tone although both were believed contributive. (See Figure 1)
- vegetative differences were in some cases contributive to the observed tonal differences between fractures and surrounding terrain; coniferous vegetation was occasionally observed to be located in fracture zones.
- subtle topographic differences reflecting faults and fractures were accentuated by slight shadowing due to the relatively low sun angle -- flight took place 8:30-10:45 AM.
- fracturing was also comparatively difficult to discern in areas of dense coniferous tree cover.
- outcrops which would normally be difficult to see on wooded slopes were enhanced by snow cover as were bedding planes making possible

the determination of strike and dip of the rocks from low altitude photography; rapid location of large bedrock outcrops is important in reconnaissance geologic work.

- snow cover also tends to enhance terraces along major streams and rivers; snow blanket acts as a pseudo - radar and accentuates micro-relief.

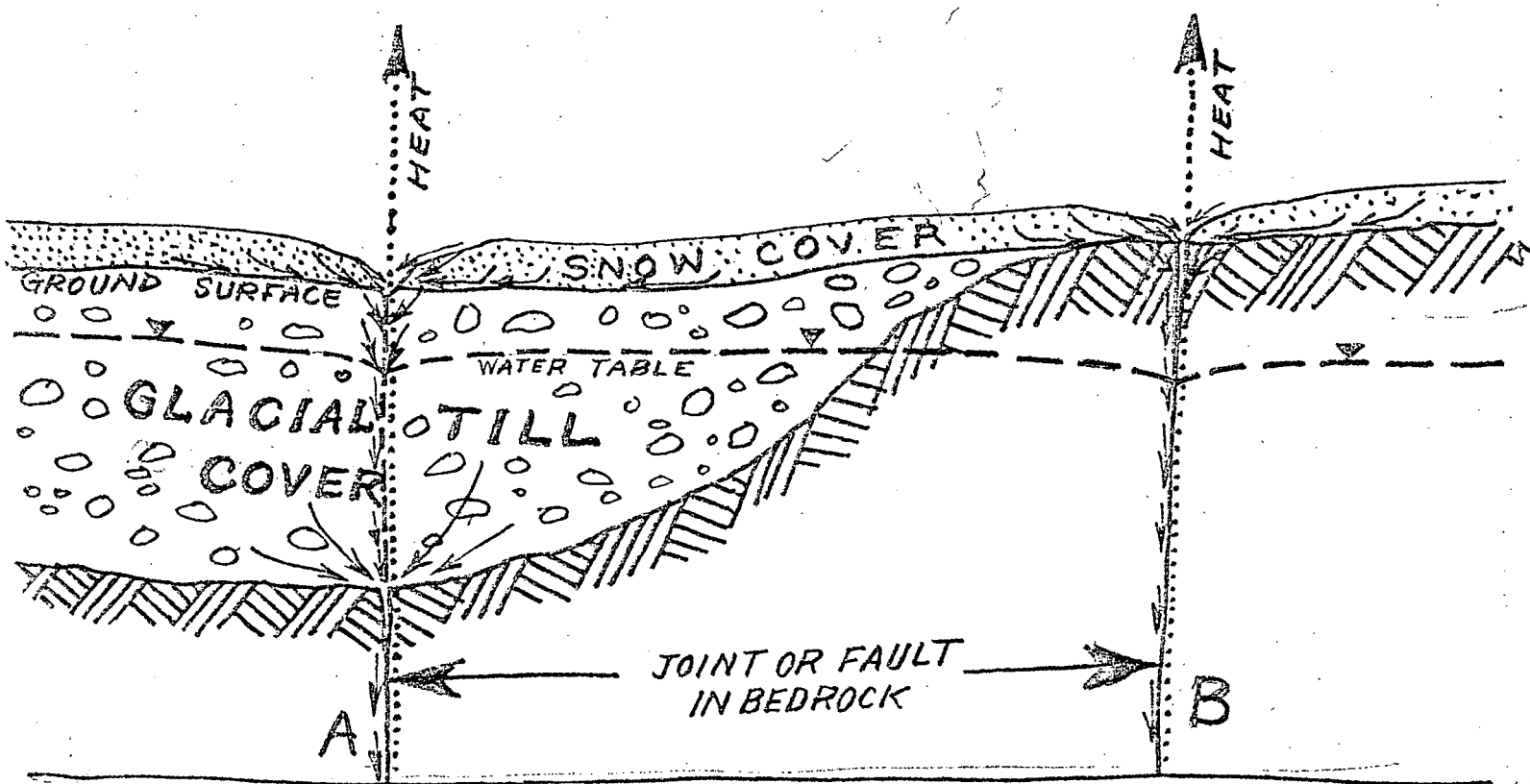
LAND USE DISCRIMINATION (Based on Snow Cover


Characteristics)


- Land Use Categories --DeciduousForest
(Which Can Be Identified
Utilizing Snow Cover) Coniferous Forest
Utilizing Snow Cover) Open Spaces (Grassy Cover)
Stubble Fields
Unvegetated Fields (Bare Soil)
Urban Areas
- Deciduous/Coniferous Boundaries Strengthened By Increased
Tonal Contrast.
- Stubble Fields - Slightly Darker Tone Than Barren Fields
- Orchards - " " " Stubble "
- Deciduous - " " " Orchards
- Coniferous - Much " " Deciduous Cover
- Some Conifers Retain Snow On Their Boughs However Even These
Have A Dark Tone.

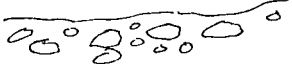
OBSERVATION SUMMARY


- Snow Cover Deepest On Slopes Of High Mountains and In Bottoms Of Deep Narrow Valleys; Snow Cover Thinnest On Windswept Open Areas And In Urban Areas
- Enhancement Of Fractures By Snow Cover Was Aerially Observed
- Darker-Tone Of Fracture Lineaments Was Believed Due To Topographic Shadowing and Differential Melting (Figure 1).
- Aerially Observed Fracture Detail Was Greatest In Areas Of Deciduous Vegetative Cover
- Slope Aspect Appears To Have the Greatest Effect Of Any Factor On Snow Melting Patterns After A Relatively Even Cover Has Been Deposited (e.g. >3 inches).
- Approximately Six Land Use Categories May Be Readily Distinguished Using Varying Tonal Contrasts Afforded By Snow Cover




EXPLANATION -- BEDROCK SURFACE — 

SNOW COVER — 

GLACIAL TILL COVER — 

GROUND-WATER TABLE — 

HEAT MOVEMENT — 


MELT WATER MOVEMENT — 

FIGURE 1 - Diagram showing the probable mechanics of snow enhancement of fractures and joints for areas covered by glacial deposits (A) and where bedrock is exposed at the surface (B). Heat, released from the rock through joint openings, migrates upward and melts snow along its path at the surface while the water from the melting snow tends to migrate toward the joints and percolates downward along the joint to the groundwater table and into the bedrock.

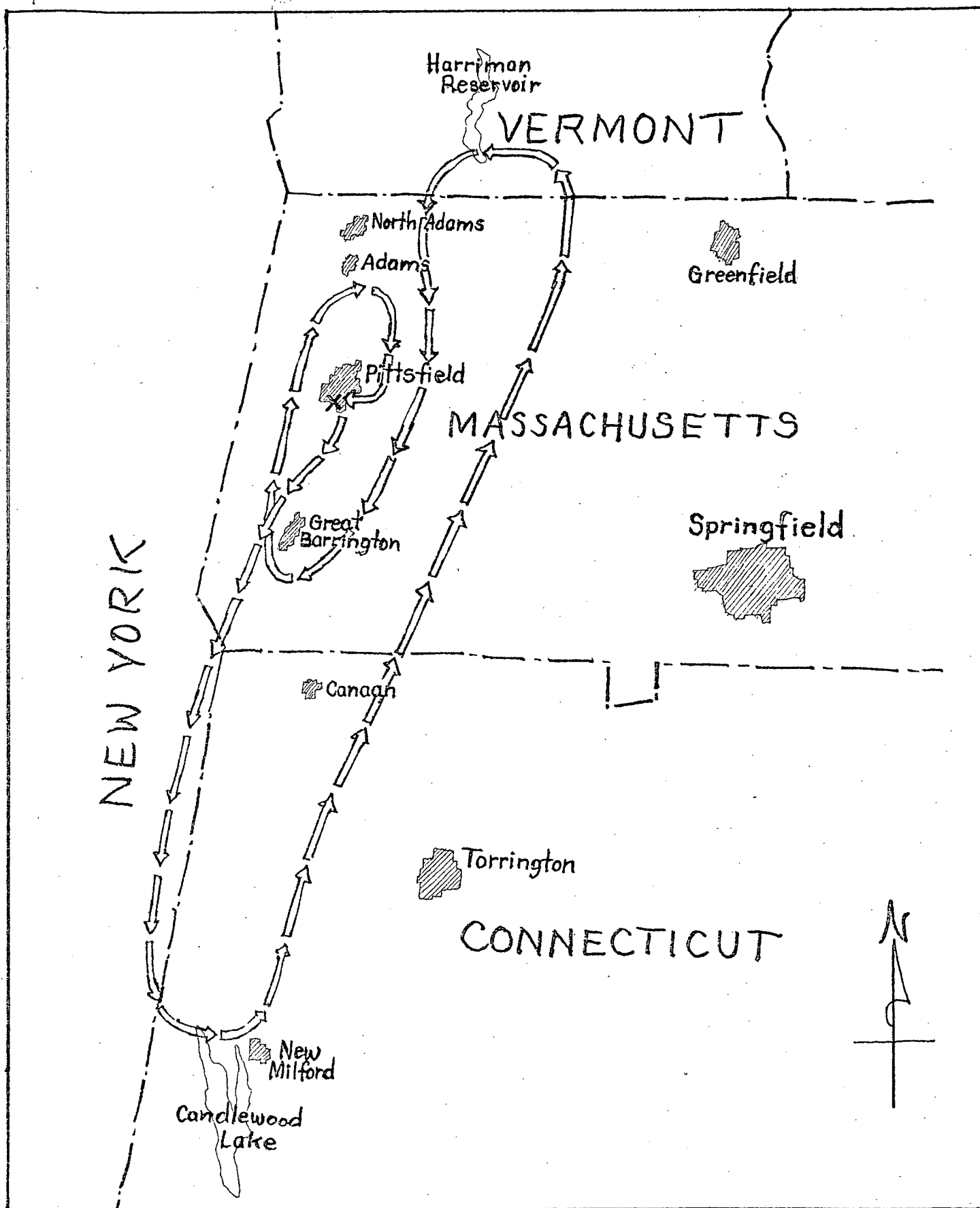


FIGURE 2 - Map showing route of low-altitude underflight beginning and ending at Pittsfield Airport. Arrows indicate direction of flight path.



FIGURE 3. View looking east from State Route 8 near Adams, Massachusetts showing snow enhancement of bedding planes in black, gneissic rock. Apparent dip measured from photograph is about 35° southwest. Without snow cover, the dark rocks would be barely visible against the dark soil and fallen leaf cover.



FIGURE 4. View north from Quabbin Reservoir, Massachusetts showing snow enhancement of cleared paths for transmission lines. Transmission line and pipeline paths are visible as white linear features against a darker background of tree cover whereas fracture traces are generally seen in snow cover as dark lines of snow melt or topographic shadowing.

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APPENDIX C

APPENDIX C

EXPLOITATION OF ERTS-1 IMAGERY UTILIZING SNOW ENHANCEMENT TECHNIQUES

Frank J. Wobber and Kenneth R. Martin
Earth Satellite Corporation
Washington, D.C. 20006

ABSTRACT

Photogeological analysis of ERTS-simulation and ERTS-1 imagery of snow-covered terrain within the ERAP Feather River site and within the New England (ERTS) test area provided new fracture detail which does not appear on available geological maps. Comparative analysis of snow-free ERTS-1 images has demonstrated that MSS Bands 5 and 7 supply the greatest amount of geological fracture detail. Interpretation of the first snow-covered ERTS-1 images in correlation with ground snow depth data indicates that a heavy "blanket" of snow (e.g., >9 inches) accentuates major structural features while a light "dusting", (e.g., <1 inch) accentuates more subtle topographic expressions. An effective mail-based method for acquiring timely ground-truth (snow-depth) information was established and provides a ready correlation of fracture detail with snow depth so as to establish the working limits of the technique. The method is both efficient and inexpensive compared with the cost of similarly scaled direct field observations. The technique of snow enhancement appears to afford a simple [and no-cost] means of edge enhancement during the snow-covered periods. Increased tonal contrasts along the snow-covered/snow-free interface provide a form of natural edge enhancement for low resolution imagery. The investigators suggest that monitoring variation in snow melting and accumulation can supply unique fracture data unavailable during other seasons.

APPENDIX D

Snow cover for accentuating geological fracture systems—a new photogeological technique

Figure below is an Apollo-9 color infrared (CIR) photograph taken at an altitude of 125 nautical miles over the Globe, Arizona, United States, area on March 12, 1969. The approximate photographic scale (1:1,000,000) and level of detail are comparable to imagery anticipated from the Earth Resources Technology Satellite (ERTS-A). Geographic reference points shown on the photograph include the town of Globe, Arizona (G), the Superstition Mountains (M), Theodore Roosevelt Lake (TL) and San Carlos Lake (SL).

The photograph demonstrates the value of snow cover as an enhancement technique for detecting fractures and other features (note circular feature, lower right) of possible interest to the mineral exploration community. Analysis of this and small scale aerial photographs indicate that snow cover (and probably the monitoring of snow melting) enhances subtle topographically expressed lineaments as well as fracture traces. Fracture traces are the surface expression of fractures covered by weakly consolidated sediments or soils. Fracture traces are photographically expressed as bare ground areas (dark photographic tones) which starkly contrast with the white tones of surrounding snow-covered areas. The detectability of subtle lineaments is reduced because this tonal contrast is not evidenced in snow-free areas.

Within the snow-covered area, selected lineaments, which appear to be fracture traces or faults, have been mapped (black arrows). These lineaments are easier to detect within the snow-covered compared to the snow-free area. The primary cause for this enhancement effect appears to be variations in melting rates which occur over materials of different lithology and/or permeability. Fractures and faults generally have higher permeabilities than surrounding areas and can store moisture and raise their heat capacity so that freezing

does not occur as quickly. New snowfall therefore melts off rapidly.

A comparative interpretative effort in snow-free versus snow-covered areas (white arrow) was conducted to identify significant lineaments. Fewer numbers of detectable lineaments were identified in snow-free areas assuming similar lithologies. This suggests that snow enhancement is a valuable tool in fracture detection and analysis. Not all lineaments detectable in snow-covered or snow-free areas are geological in origin. Man-made structures (e.g., transmission lines, pipelines, highways, railroads, etc.) may be confused with natural lineaments in analysis of small scale imagery. One such lineament (dashed line) which appears in the upper left of the photograph is a multiple lane-divided highway, U.S. 80-89. In close proximity to the highway are the checkerboard field patterns of irrigated croplands (F) near the Gila River. A thinly veneered pediment

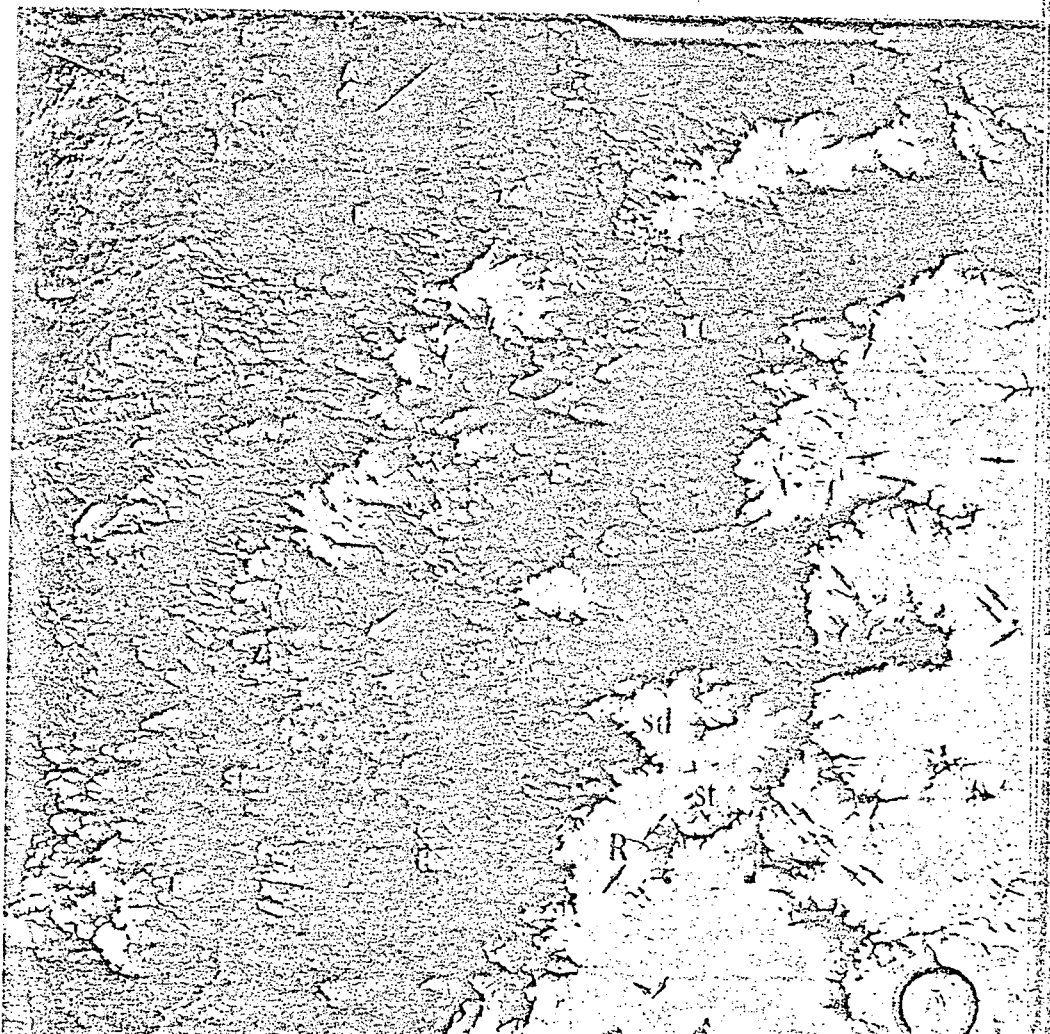
By Frank J. Wobber
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(P) grades into an alluvial apron or bajada (B) formed by coalescing alluvial fans. Other pediments and bajadas occur and can be identified from the photograph.

The problem of distinguishing snow cover from cloud cover is well exemplified in several areas on the photograph. Small areas of snow cover(s) could be difficult to differentiate from singular or wispy cloud formations. Cloud formations, however, are distinguishable in that they tend to obscure surface detail, cast noticeable shadows, and often have unique texture and form.

Tonal variations within snow covered areas suggest differences in snow depth, which may be a function of topographic obstructions, wind direction, solar aspect, or other factors

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influencing snow accumulating and melting. Dark tones of some snow-covered areas (ST) may be caused by surficial bedrock or sediment showing through thin snow cover. Nearby areas show relatively bright white tones apparently due to deeper snow accumulation (sd).

Drainage patterns, which provide evidence of fractures, are also accentuated in snow covered terrain. Several patterns exhibiting right-angle tributary entrance (R) probably represent fracture controlled drainage ways. Drainage patterns leading into San Carlos Lake (SL) and particularly the pattern at (H) readily show the effect of shadows introduced by low angle solar illumination, which was about 33° at the time of this photography. Solar illumination as low as 20° can highlight certain

areas by increasing the contrast of geologic features. However, image degrading atmospheric scattering is also increased and surface detail may be lost in shadows.

The authors suggest that the enhancement introduced through the combination of low solar angle and snow cover can serve the mining industry as a useful photogeological technique. The technique of snow enhancement facilitates detection of subtle fracture systems and lithological changes and can have immediate applications in studies requiring regional structural analysis.

Snow enhancement can also ensure further utilization of wintertime imagery, and assist the photogeologist in reconnaissance studies of permanently snowcovered areas. The utility of snow enhancement as a photogeological tool is being investigated by the authors as part of a NASA ERTS-A experiment.

END.